phrase, has never been more terrible exemplified than by Germany, yesterday wielding her vast might of intellect and muscle to dominate the world; to-day cast down to the very dust and utterly impotent.

Nature herself, working through the process we have named evolution, has produced an agency, the human reason and intelligence, one of the main purposes of which is to find a better way, *i. e.*, a more efficacious, more certain, and less destructive way than war for solving problems of human preservation and realization.

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SOME NECESSARY STEPS IN ANY ATTEMPT TO PROVE INSECT TRANSMISSION OR CAUSATION OF DISEASE

THE study of the causation of disease is attracting far more attention to-day than it ever has in the past, but it is to be regretted that there is not a larger proportion of this effort being directed toward locating the possible intermediate hosts and invertebrate carriers.

Many excellent investigations have been carried out with all other phases complete, but the question of invertebrate carriers is often left in a very indeterminate stage. The majority of the investigations which have been seriously undertaken to determine invertebrate carriers have been conducted on other continents than ours. There is a great field for investigation along these lines open to investigators in America. In order to stimulate such research, I have attempted in this paper to set down some of the necessary steps for successful investigation.

I. COOPERATION

I consider essential to a thorough investigation of disease transmission, the establishment of a perfect working agreement and hearty cooperation between one or more physicians and diagnosticians, one or more parasitologists, and one or more entomologists. It is not safe nor does the effort bring the proper amount of credence, when one man attempts to do the whole work. Each phase of such an investigation should be handled by an expert on that phase. The day of the solitary investigator is past and we are now in an era of group-investigations which carry with them weight and conviction. Of course certain preliminary steps may easily be taken by any one member of a proposed group or it may be possible that they may arrive at an advanced stage by independent work, but the time will come in each investigation when a cooperation of investigators will attain the most satisfactory results.

II. WHERE SHOULD THE INVESTIGATIONS OF INSECT TRANSMISSION BEGIN?

There are two distinct lines of approach to this problem of insect transmission. The first is to work from the known disease and to ascertain by experimentation what species of insects might be concerned in its transmission. The other line of approach is to make a study of all the insects whch might be involved in disease transmission and to obtain, by cultures and microscopic studies, a knowledge of the parasitic organisms normally and occasionally found in these insects. Working on this line of investigation, one might in time of an epidemic start with insects visiting excreta and attempt to ascertain whether the organism of the disease at that time epidemic occurs in any of these insects.

The first line of investigations would rise from public necessity and probably be initiated by physicans and parasitologists, or by the suggestion of entomologists.

The second line of investigations would probably originate as problems assigned by a professor or head of a laboratory to students or investigators under his direction. It is highly desirable that such studies be commenced in as many institutions as practicable in the near future. Such investigations will include bacteriological studies, protozoological studies and helminthological studies, as well as investigations of the life histories of the insects, and the possible connection between them and disease transmission.

III. PLAN OF OPERATION

Before starting out on any lines of experiment in this subject, there should be written down in concise form the facts already gleaned on the practical problems of the theories which have occurred to the various members of the group. A clearly outlined course of action should be made and be carefully discussed and then the various steps in the investigations thus outlined should be read and modified to meet the changing views resulting from the experiments. The course of the work should always be kept plainly in view. Each step should be rigorously and skeptically scrutinized for defects.

In as much as the investigation from this point will consist of the answering by observation and experiment of a series of pointed questions, I shall proceed with my discussion in the form of queries. Probably many other vital queries will occur to the reader, but it is more than possible that he may overlook some of these if not set forth here. When each query is satisfactorily answered the problem is practically solved.

IV. HOW CAN AN INSECT BE INVOLVED IN DISEASE TRANSMISSION

Insects[1] may be involved in disease transmission either by the transmission of an organism or the inoculation of a toxin or they may be an intermediate phase in the life cycle of an organism, but not come directly in contact with the final host.

1. *What kind of organisms can insects carry?*—It has been demonstrated that insects can carry bacteria, many types of protozoa and many species of parasitic worms, and also that certain species of insects may be instrumental in carrying eggs of other species of insects which cause disease.

2. *In what manner may insect toxins bring about disease?*—Many species of insects bite, and inoculate, at the time of the bite, a toxin which may at times cause serious trouble.

Some invertebrates inoculate the toxin by means of the mouth, some by means of a claw, some by means of a caudal appendage, others by means of the ovipositor. In some cases the invertebrate penetrates the skin with its mouth parts and as long as it is adhering, toxins are created which may in certain cases cause severe paralysis or death. The accidental eating of certain insects in food will cause poisoning because of the toxins contained in the bodies of these insects. It is believed, but not yet satisfactorily demonstrated that the pollution of food by the excreta of certain insects may cause certain nutritional diseases.

The presence of certain insects in the tissues causes severe irritations and often the formation of toxins.

3. *Can insects themselves cause disease?*—Many species of insects are known to live parasitically upon the bodies of man and animals and by their constant sucking of blood or gnawing, cause skin diseases. Other species of insects habitually lay their eggs on or in the flesh and breed commonly or exclusively in living flesh, causing a destruction of the tissues. Many species of insects are dependent upon mammalian blood for the necessary nutriment to bring about reproduction. Some insect larvæ are blood suckers. It is not at all uncommon for insect larvæ to be ingested in food and for them to continue their development in the intestines or other organs, often at the expense of the tissues. In some parts of the world insects are eaten as food by the natives, sometimes in a raw state, and it is not uncommon in such case for the natives to be infected with parasitic worms which pass their intermediate stages in the bodies of these insects.

4. *Where may insects obtain the organisms which cause disease?*—Disease organisms may be taken up by insects directly from the blood of an infected host or they may be obtained by sipping infected surfaces of the body or taken up from the feces or other excretions of an infected host. The insect may take up the organisms from these excretions either in its larval or its adult stage.

5. *How can the insect transmit the organ-*

[1] By insects, in this article, are meant those forms of invertebrates popularly called insects, including the Arthropoda.

ism?—The organism may be transmitted by the insect by direct inoculation through the proboscis, involving the active movement of the parasite, or the passive transmission of the parasite in the reflex actions which take place in the sucking of blood. The organism may be externally carried on the beak of the insect and mechanically transmitted at the time of sucking. It may be located in the mouth parts of the insect and burrow through at the same time the insect is feeding. It may be in a passive state on the insect and become stimulated to attack the host when it comes in contact with the warm body. The organism may be regurgitated by the insect on the body of its host and obtain entrance by its own activity, or by being scratched in, or by being licked up by the host.

On the other hand, the organism may pass through the insect, and pass out in its feces, or in malpighian excretions. It may be washed into the wound made by the sucking of the insect, by fluids excreted at the time of the feeding. It may remain in the feces on the host and ultimately be scratched in or licked up by the host.

The organism may be taken up by the insect and never normally pass out of the insect, but be inoculated by the crushing of its invertebrate host upon the body, and the scratching of infected portions of the insect's body into the blood.

Quite a series of disease organisms find their way into the hosts because of the habit of the host of feeding upon insects.

6. *What is the course of the organism in the insect?*—If the organism is taken up by the insect in its larval stage, the organism may pass directly through the larva and out in its feces and may quite conceivably pass in this manner through insect after insect larva before it finally finds a vertebrate host. The organism may be taken up by the larva and remain dormant in some portion of the larva's anatomy, or, on the other hand, it might undergo considerable development and multiplication in the larva and remain there through all the metamorphosis of the insect until the latter arrives at maturity, at which time development of the organism may begin or may continue.

Upon being taken up in the blood by the bite of the insect, the organism may lodge in the œsophagus and carry out all its metamorphosis there, or in some of the organs of the head and find its way into the salivary glands and through the salivary secretions into a new host.

It may, on the other hand, pass back into the gut, or into the stomach; from the stomach its path may lead in many directions. It may pass on in its course of development into the rectum and out in the feces, or it may enter the fatty bodies or pass into the general cavity of the insect, or it may migrate forward into the œsophagus and into the labrum; and it may pass into the malpighian tubules, or into the ovaries.

The organism may enter the eggs and remain therein through their development into the larvæ or nymphs and be transmitted at some stage of the development of the second generation.

7. *What is the course of the organism on leaving the insect?* The organism may leave the insect in the saliva and immediately enter the blood puncture. It may bore through the labrum of the insect at the time of feeding and enter the puncture. It may leave the rectum of the insect on the malpighian glands and be washed into the puncture by means of the secretions of the coxal glands, or some other excretions made at the time of feeding. It may be excreted in malpighian secretions, or rectal feces, or regurgitated in vomit, and may lie dormant on the skin of the host, or in the food of the host, until it is scratched into the blood, or is taken into the mouth.

On the other hand, it may be possible that the organism requires another host after the insect, and before it reaches its final host. There are cases on record of the insect being the first host, and two or three other animals in succession being hosts of later stages.

V. What is Known About the Disease to be Investigated?

It is a primary essential that all the workers be able to recognize the disease which they

are trying to study and that they be fully informed about it, so that they may be able to grasp possible solutions of their problem. They will, therefore, seek first to answer the following questions:

1. What is the history of the disease and how long has it been known? How serious has it been?

2. What is its distribution?

3. Does it occur in pandemic, epidemic, endemic or sporadic form?

4. In what seasons of the year is it most prevalent.

5. Is there any apparent relationship between its distribution and the physical, biological or climatic features of the countries where it occurs?

6. Does it affect any particular group, occupation, sex, race or nation of people, or any particular species of animal?

7. May any wild animal be considered as a reservoir?

8. Has immunity or difference of susceptibility been recognized and under what circumstances?

9. What are the symptoms of the disease?

10. What have autopsies shown?

11. What treatment has been designated?

12. What is known or suspected about its causation and dissemination?

13. What possible theories can be advanced to account for its causation and dissemination?

A little time spent in collecting those facts may save much effort later.

VI. WHAT INSECTS SHOULD BE INVESTIGATED?

A thorough entomological study of this question may prove a valuable short cut to the investigation. Many insects will be eliminated by the entomologist before he has finished his preliminary work. He will attempt to answer the following and many other questions and will probably have to answer them to the satisfaction of all his fellow workers.

1. What insects coincide in distribution with the general distribution of the disease?

2. What insects occur in peculiar habitats of the disease?

3. What blood insects occur in the locality under investigation?

4. What is the relative abundance of these insects?

5. Is there a coincidence between the season of abundance of any of these and of the disease?

6. What insects occur in the homes, nests or haunts of infected hosts?

7. What insects are found on infected hosts?

8. What insects occur in the working quarters of the patients?

9. What insects would be most apt to affect the particular group of hosts most susceptible?

10. What insects breed in or frequent the excreta of the hosts?

11. What insects are found at the food of the hosts?

12. What insects are found at the sources of the food of the hosts, such as the milk?

VII. WHAT IS NECESSARY IN THE TRANSMISSION EXPERIMENTS?

The investigations which have preceded will have narrowed the question down to certain species or groups of insects which need to be critically studied. All of those insects which come in contact with the blood of the patient, or the food of the patient, or the feces of the patient, must be given special attention. At this point the bacteriologist, protozoologist or the helminthologist finds his special work beginning. There will be many points which must be worked out by cooperation of the parasitologist and entomologist.

Considering first the blood-sucking insects, it is necessary to determine:

1. Can the particular insect take up the organism with the blood?

2. Does the organism pass into the intestinal canal or does it stop at some point en route?

3. To what extent is the organism digested by the insect?

4. In what organs of the insect can the parasite be demonstrated from day to day?

5. Are any changes in the organism demonstrable?

6. What path does the organism seem to follow in the insect's body from day to day?

7. Does this movement of the organism suggest whether the transmission is by inoculation or does it suggest that the organism will pass out of the body in some of the excreta?

8. Can the organism be demonstrated in the mouth parts of the insect at the time of feeding?

9. Can the organism be found in any of the excretions of the insect?

10. How long is it before the organism reaches the mouth or the rectum?

11. What is the earliest date at which it can be found in the feces?

12. What is the earliest date at which infectivity of the host can be obtained by the sucking of the blood?

12. What is the earliest date at which infectivity can be obtained by scratching in of feces or portions of the insects?

14. Can infection be obtained by either natural or artificial inoculation without demonstration of the organism?

15. Is the infective organism or virus filterable?

16. Can the virus or organism be transmitted hereditarily?

17. At what stage of development in the second generation does hereditary transmission become possible?

18. Can the organism be taken up by the immature stages, feeding in infected excreta?

19. Can the organism be taken up by immature stages of an invertebrate feeding on the host?

20. How long can the immature forms of the invertebrate, infected by whatsoever manner, retain the organism in their system?

21. Does it stay during metamorphosis?

22. Does it undergo any changes preceding or following metamorphosis?

23. At what stage in the metamorphosis does the insect begin to be infective after taking up such organisms?

24. How long can the insect remain infected?

VIII. HOW SHOULD EXPERIMENTAL INSECTS BE HANDLED?

A large proportion of the failures in studies of insect transmission in the past have arisen from improper handling of the insects. The breeding and handling of the insects is an art in itself, just as is the culturing of bacteria or protozoa. In fact there are more diverse requirements for handling insects of different species than can be found elsewhere in the animal kingdom.

1. *What must be known about the insect before beginning transmission experiments?*—The normal conditions of life of the insect must be ascertained: its reactions to heat and cold, moisture and dryness, disturbance, color, light, odor; its food, and the proper condition thereof; its methods of reproduction, and what food is necessary for reproduction; if soil should be provided, and what conditions it should be in; if water should be provided, and whether this water should be alkaline or acid, clear or containing foreign matter, and in such case what type of foreign matter; whether the water should be still or in motion, warm, moderate or cold.

2. *What type of breeding cage should be used?*—A breeding cage must be used which will most nearly enable the experimenter to keep the insects under control and yet reproduce essential conditions for maintaining reproduction. Much of this information is normal healthy life of the insects and normal available in entomological literature. Many insects probably involved in disease transmission have not been properly studied and breeding technique is yet to be worked out.

3. *Water is necessary in some form in practically all insect breeding.*—There are more failures to properly breed insects traceable to improper humidity, or to the lack of moisture in the proper form for the insects to drink. Much detailed observation may be necessary to obtain this important information in the case of many insects.

4. *There is a combination of temperature and humidity most favorable for life, for each species,* and *differing from one species to another.*

4. *The food of an insect must be in a particular condition in order to obtain normal breeding.* It may require a certain degree of

immaturity, ripeness or fermentation. It may require a certain degree of desiccation.

Many other details must be attended to by each specialist involved in the investigation, and we probably have yet to see a single disease problem which has been completely rounded out and solved for future generations.

IX. HOW SHALL WE RECORD OUR OBSERVATIONS?

Undoubtedly the most satisfactory method of making a large series of records is to use some type of loose-leaf card or sheet filing system. By such means one can always keep in an orderly arrangement all the facts so far obtained. In the case of investigations of the causation of a given disease, one of the most satisfactory methods which has been used for recording observations is to prepare a little blank booklet, which will fit the filing system, in large quantities, each book to represent a case. This book should contain pages for each phase of the question, with blanks covering all kinds of minutes about this phase. The whole series of observations can be tabulated for each point.

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THE U. S. FOOD ADMINISTRATION'S WAR FLOUR

The U. S. Food Administrator, Mr. Herbert Clark Hoover, met and solved one of the greatest problems of the war. Prompt and seemingly drastic action was necessary in order to conserve wheat and vanquish the specter famine. The way in which this was achieved is so well known that recounting is unnecessary.

Bread is a nation's chief food, and in order to maintain an adequate supply during the war there were but two courses open for the Food Administrator to follow: To require the use either of substitutes, or of whole wheat flour, also known as long extraction flour. As head of the commission for relief in Belgium, Mr. Hoover was familiar with the results arising from the exclusive use of whole wheat flour in rationing a nation, and they were such as not to warrant a repetition of the experiment in the United States. It is most fortunate that no impractical dreamer, bent upon repeating an experiment that had failed was in charge of the U. S. Food Administration. Mr. Hoover's plans for the conservation of food and wheat in particular, rested upon basic scientific principles.

At the time Mr. Hoover assumed control there was a shortage of wheat and a fair supply of other cereals, particularly corn and barley. It was a question as to the best use of these cereals for human and animal foods. Corn and barley alone were not suitable for bread making, as they lack the gluten or binding material of wheat. Gluten is contained only in the floury part of the wheat and there is none in the wheat bran except that present in any flour that may have failed to be separated from the bran. As wheat bran and other wheat by-products contain no gluten binder they are on a par with corn and barley so far as physical bread-making value is concerned. The Food Administration took a broad view of the question and recognized that in addition to bread there must be maintained an adequate supply of milk and animal fats as pork.

Naturally the question hinged upon the relative merits of bran and corn and barley flours as human and animal foods. All available data plainly indicated that a pound of corn or barley flour furnishes the human body with more digestible protein and available energy than a pound of wheat by-product. In the animal ration, however, the wheat by-product has a higher productive value than the corn or barley.

Some recent experiments of the U. S. Department of Agriculture, conducted during the war by Arthur D. Holmes, specialist in charge of Digestion Experiments, Office of Home Economics, have an important bearing upon this subject. He reports that in eight digestion trials with men fed on fine bran bread in a simple mixed diet, an average of 44.7 per cent. of the bran protein was digested and 56.6 per cent. of the bran energy was available. In the case of unground bran 28 per cent. of the protein was digested and 55.5